U.S. Geological Survey-
Montana Water Science Center

Peter McCarthy
Hydrologist
406-457-5934
pmccarth@usgs.gov

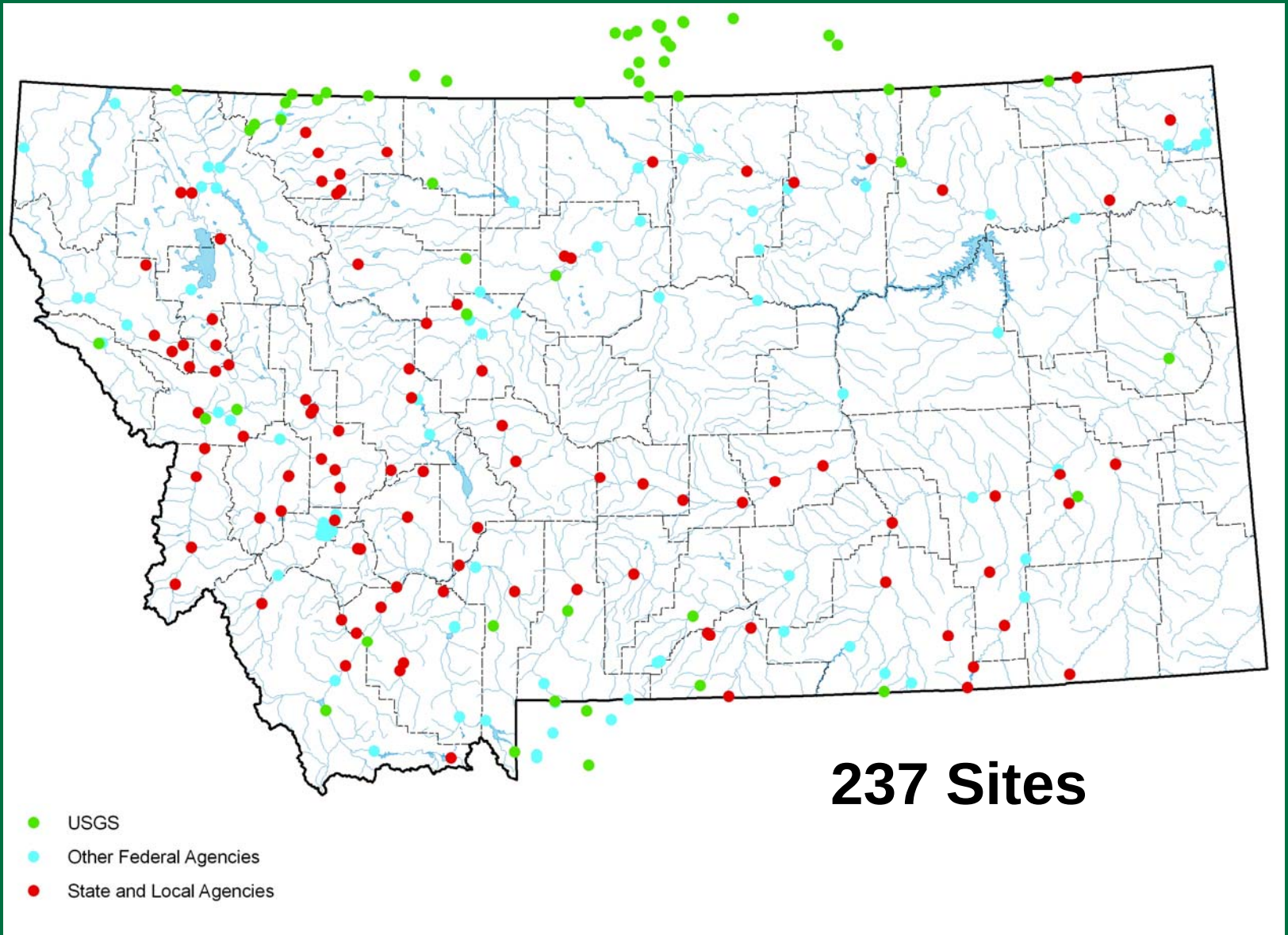
U.S. Department of the Interior
U.S. Geological Survey

Overview of Presentations

- Montana Water Science Center
  - Data collection activities
  - Groundwater and surface-water studies
- Flood Frequency Analyses
- StreamStats
- Computing Estimates of Flood Frequency for Ungaged Sites using Parrett's WRIR 03-4308

USGS

Active Streamgages



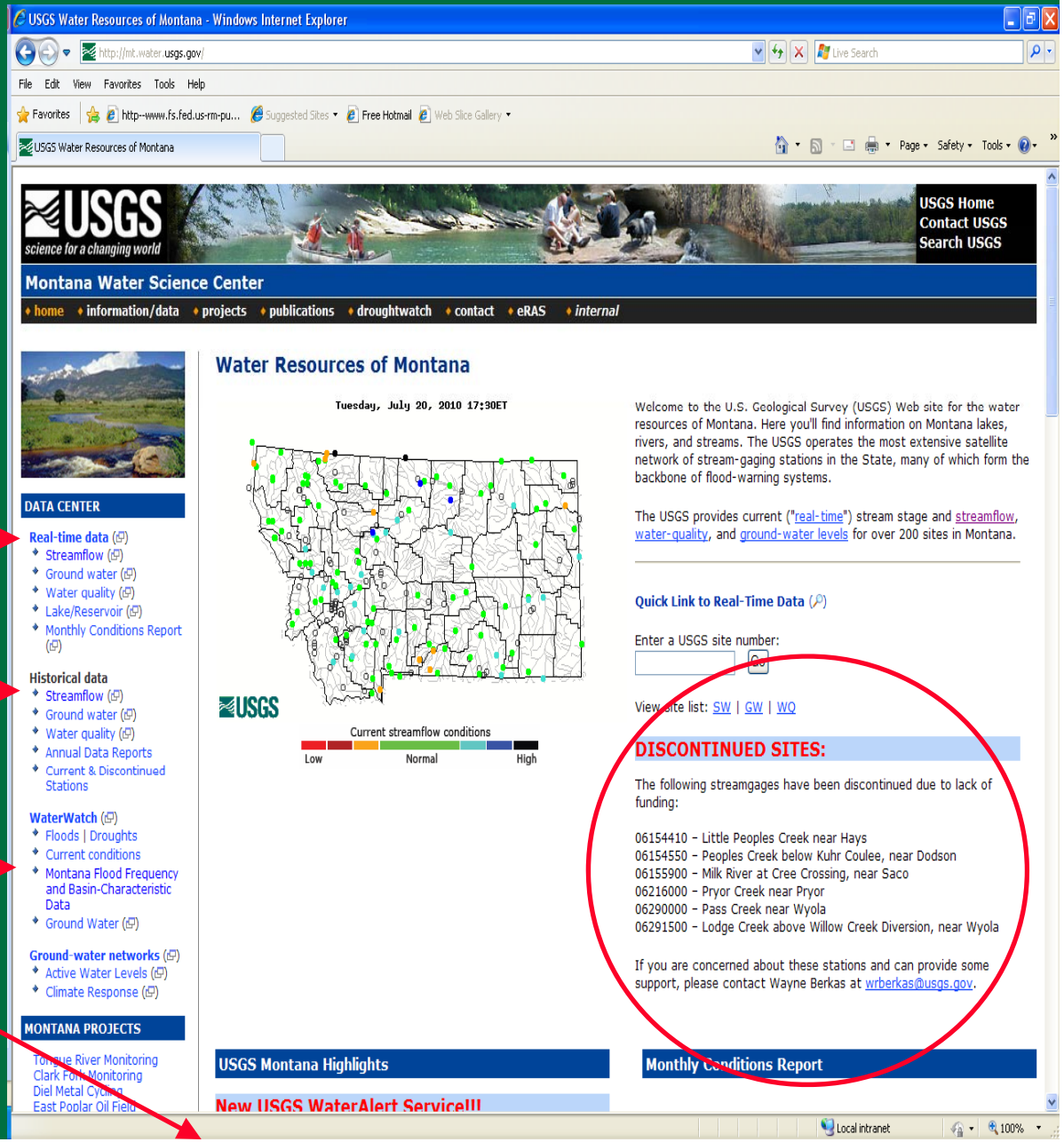
http://mt.water.usgs.gov

Real-time data

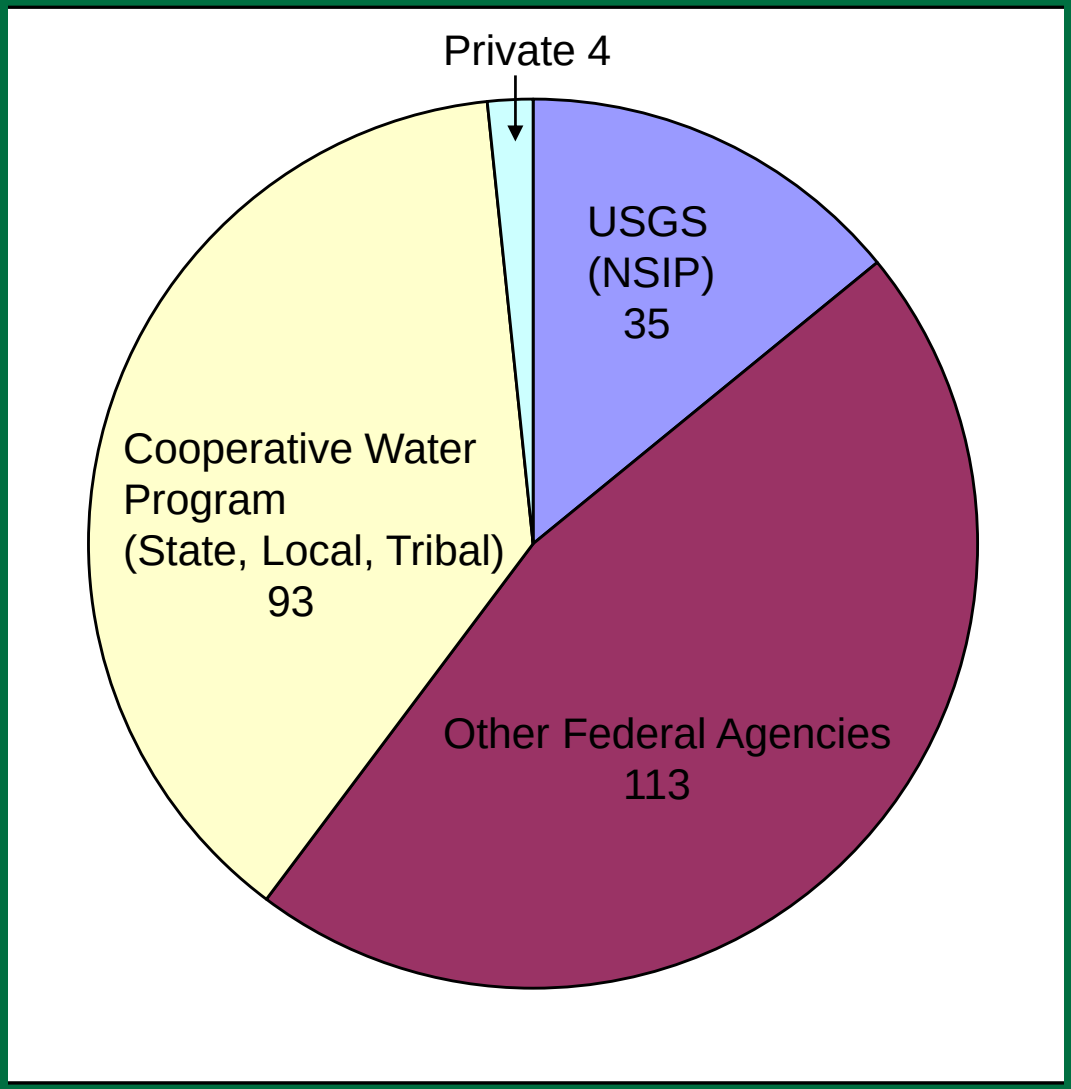
Historical data

Flood Frequency

Recent Studies



Active Streamgages by cooperator



Stations and Cost (FY10)

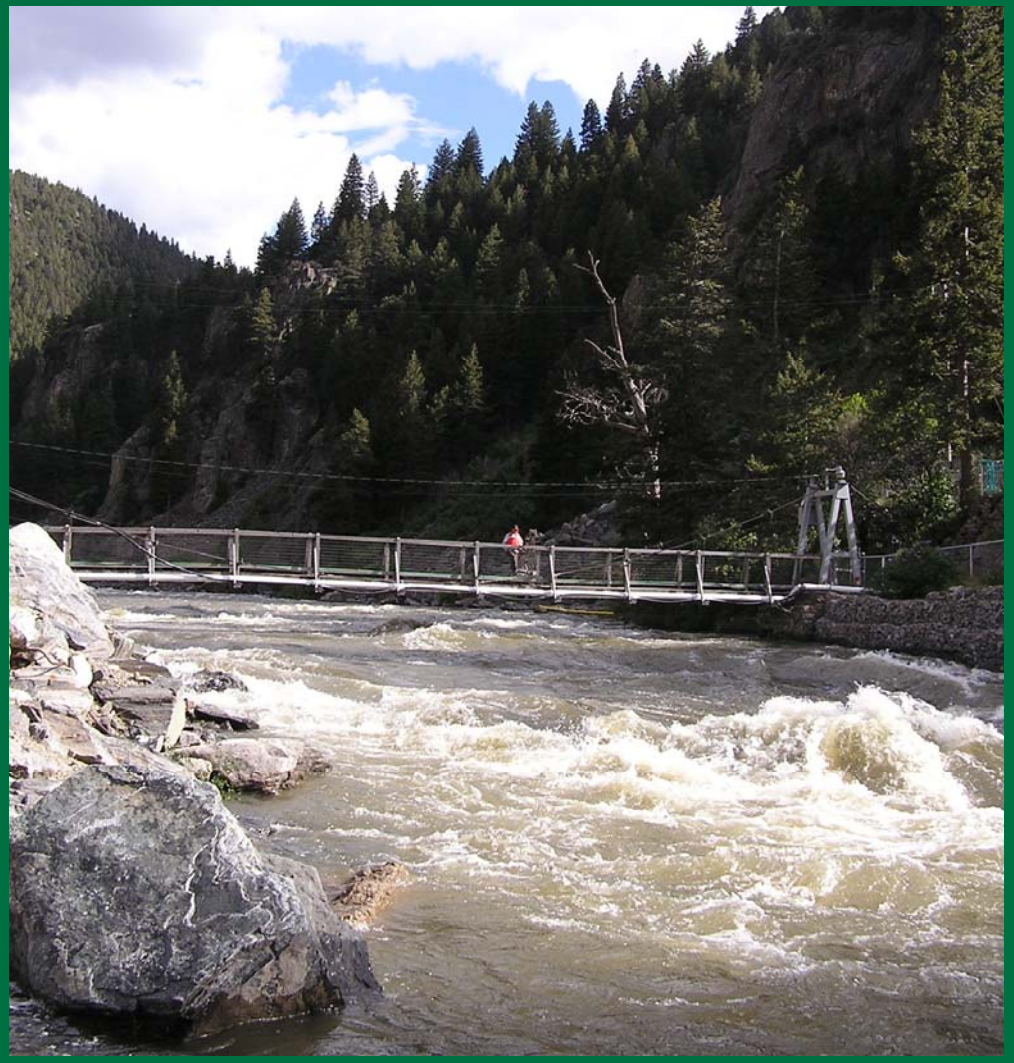
237 Streamgages

164 Full year Stations

@ $15,500

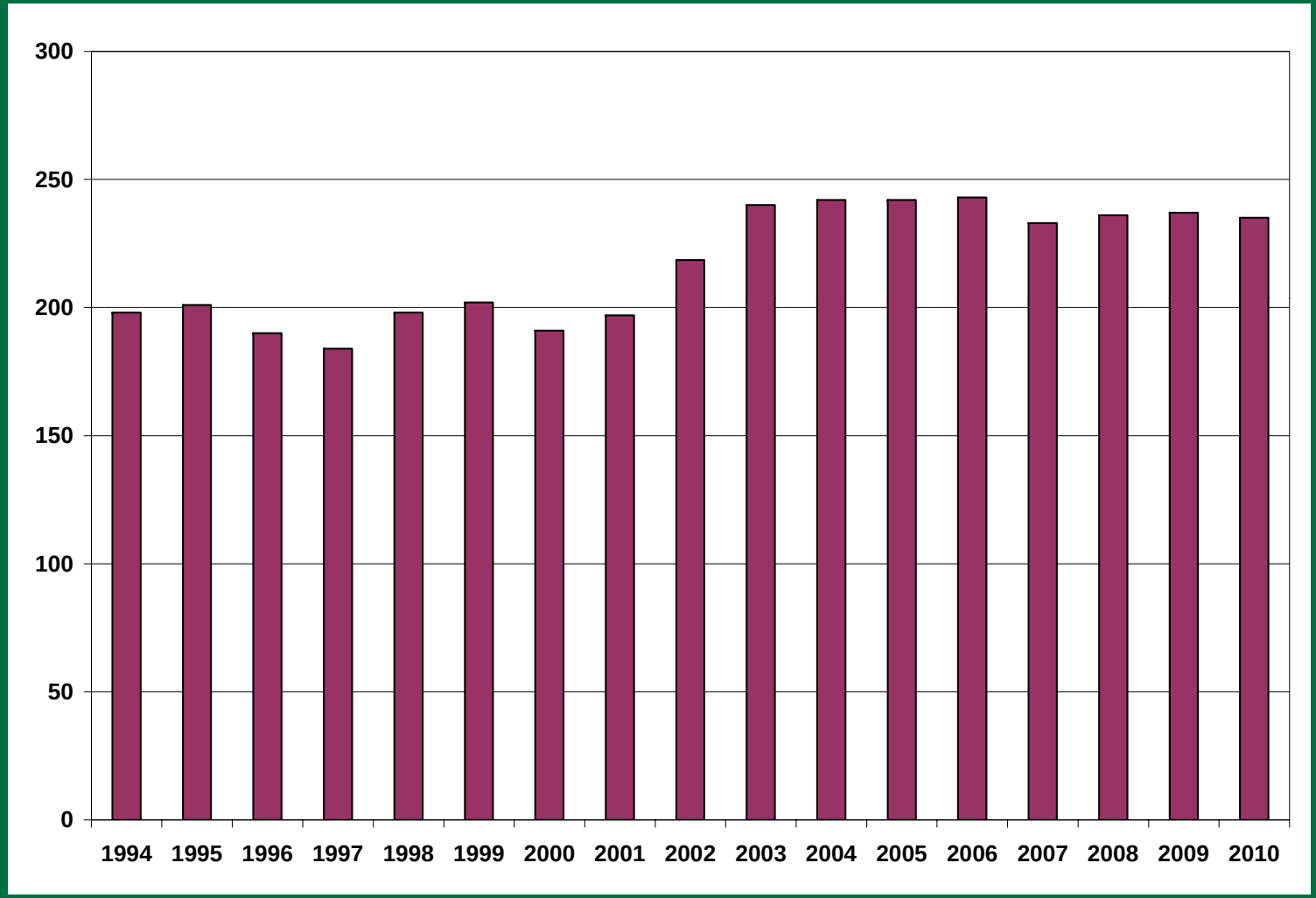
73 Seasonal Stations

@ $10,500



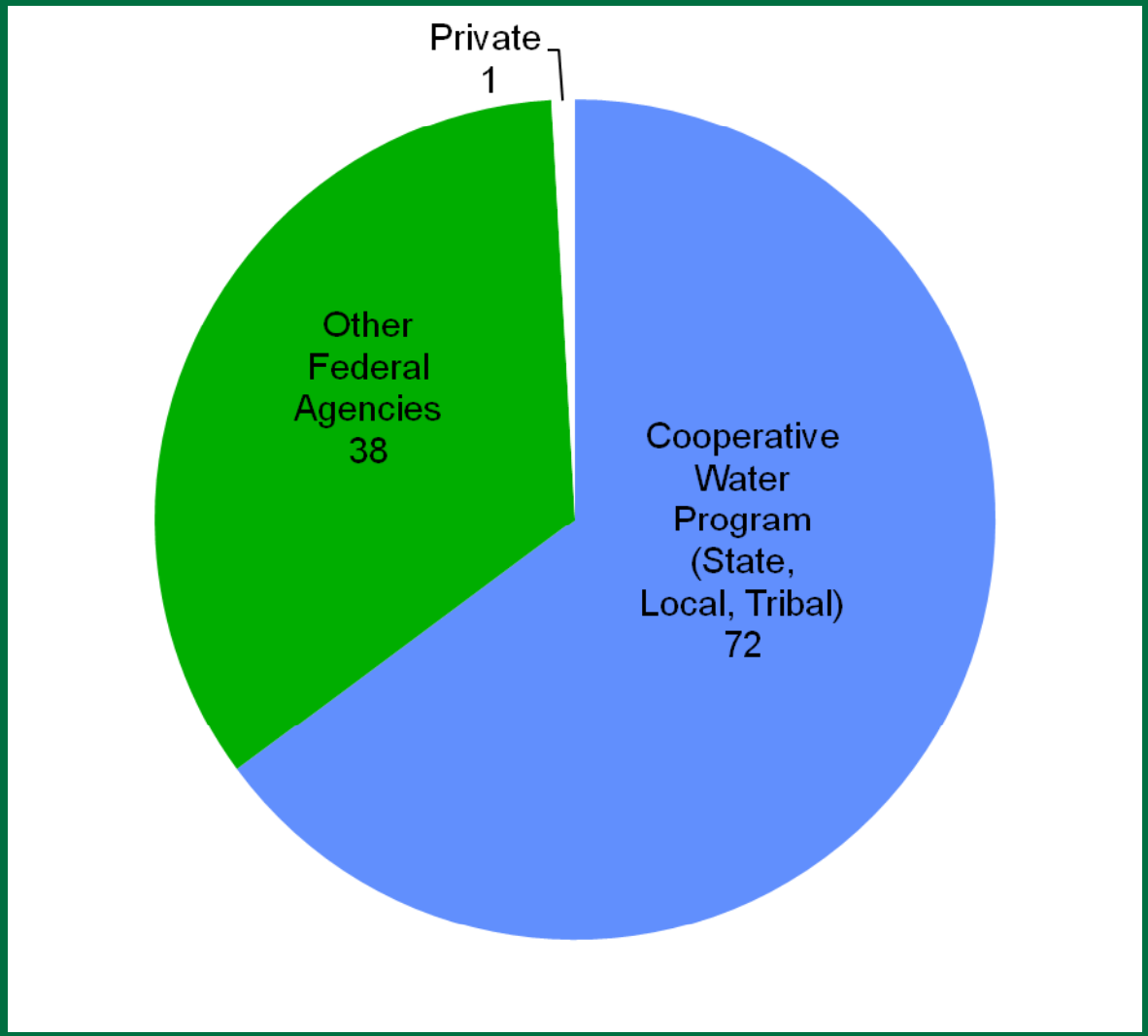
USGS

Number of Gaging Stations by Year



USGS

Active Water-Quality Sites



USGS

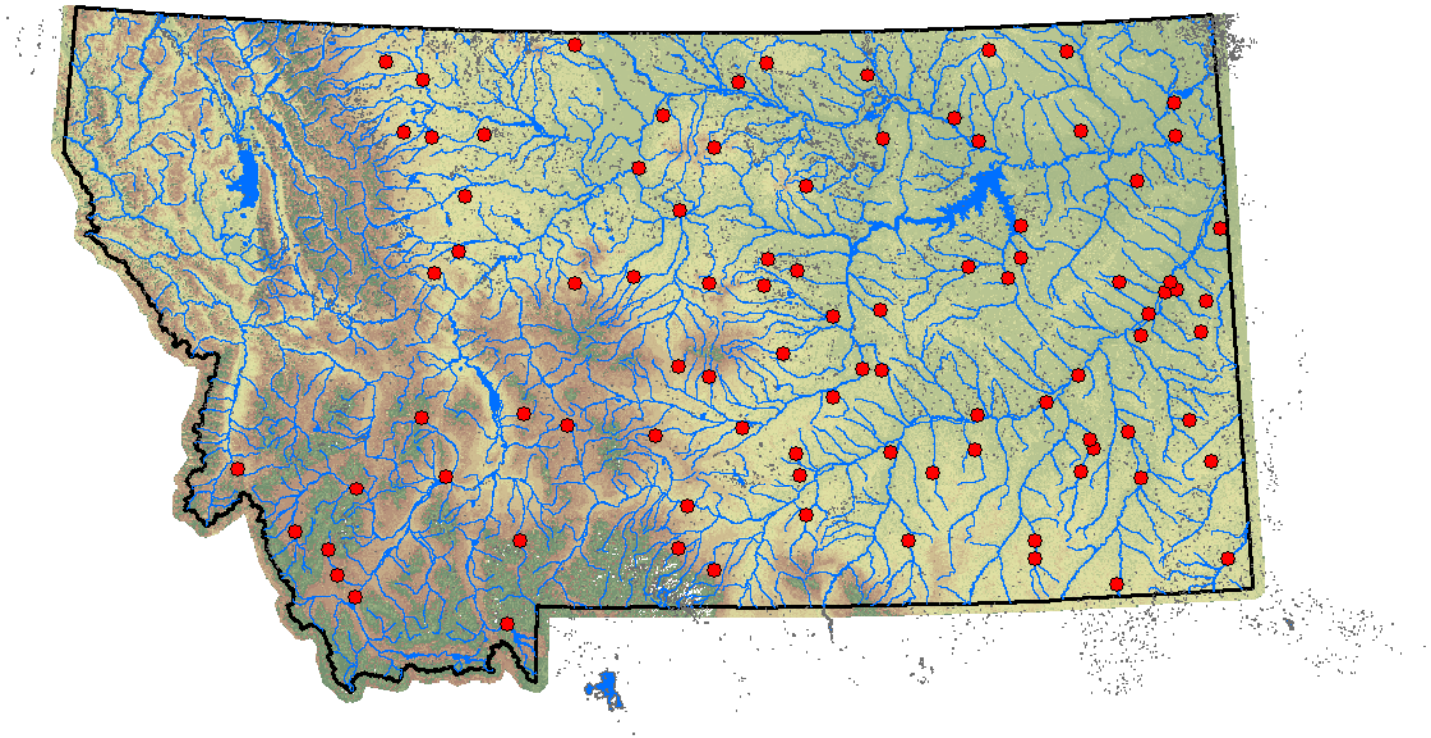
Active QW Sites

- 38 Temperature Monitors
- 13 Specific Conductance Monitors
- 6 Turbidity Monitors
- 82 Periodic QW Sites

USGS

Crest Stage Gages

97 Crest Stage Gages



Groundwater and Surface Water Studies

- **Groundwater Studies**
  - Groundwater quality
  - Groundwater and surface water interactions
  - Groundwater mapping
- **Surface Water Studies**
  - Surface water quality
  - Floodplain studies
  - Climate change studies
  - Bridge/pier scour monitoring
  - Streamflow statistics

USGS

USGS
science for a changing world

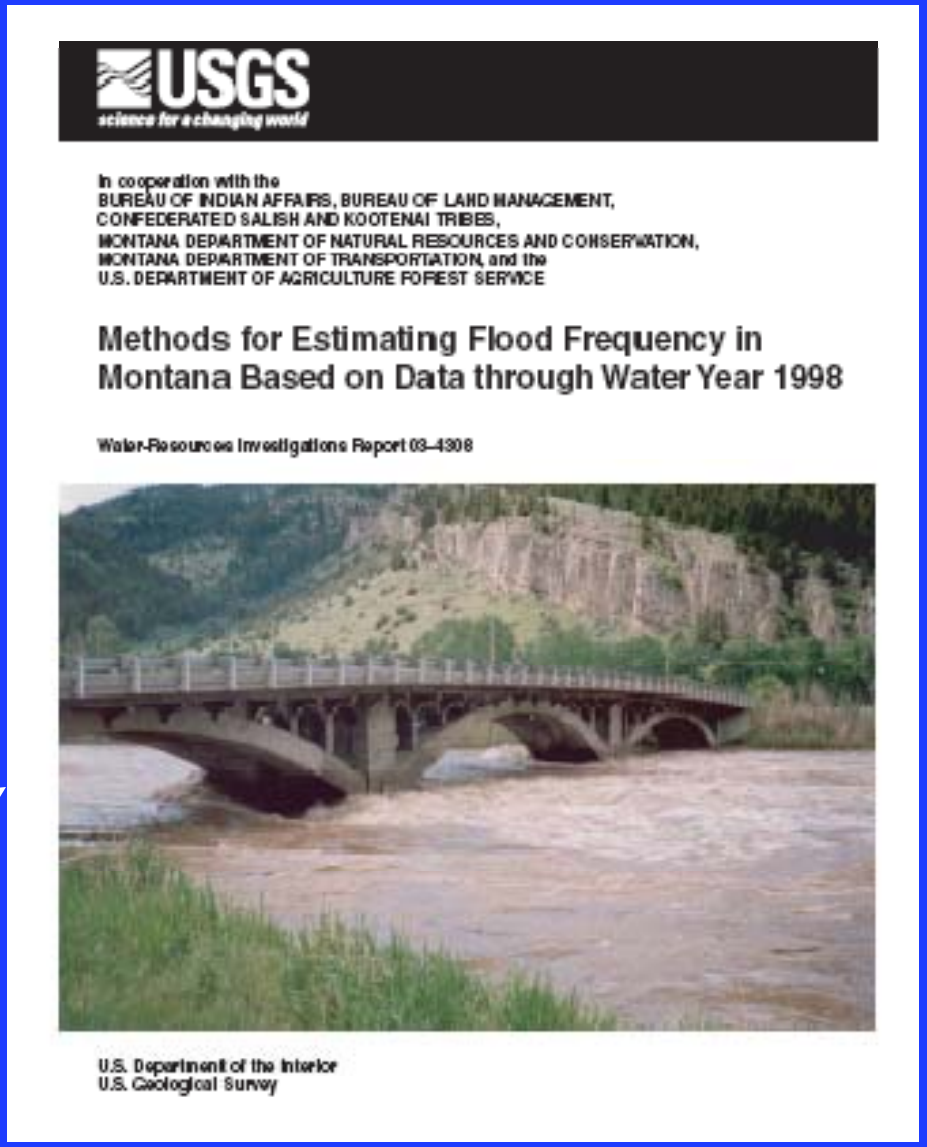
Updating flood-frequency estimates for the USGS gaging station network in Montana

In cooperation with
Montana Department of Transportation and
Montana Department of Natural Resources and Conservation

U.S. Department of the Interior
U.S. Geological Survey

Prior Studies

- A method for estimating magnitude and frequency of floods in Montana (1976)
- Revised techniques for estimating magnitude and frequency of floods in Montana (1981)
- Methods for estimating magnitude and frequency of floods in Montana based on data through 1983 (1986)
- Analysis of the magnitude and frequency of floods and the peak-flow gaging network in Montana (1992)
- Methods for estimating flood frequency in Montana based on data through water year 1998 (2004)



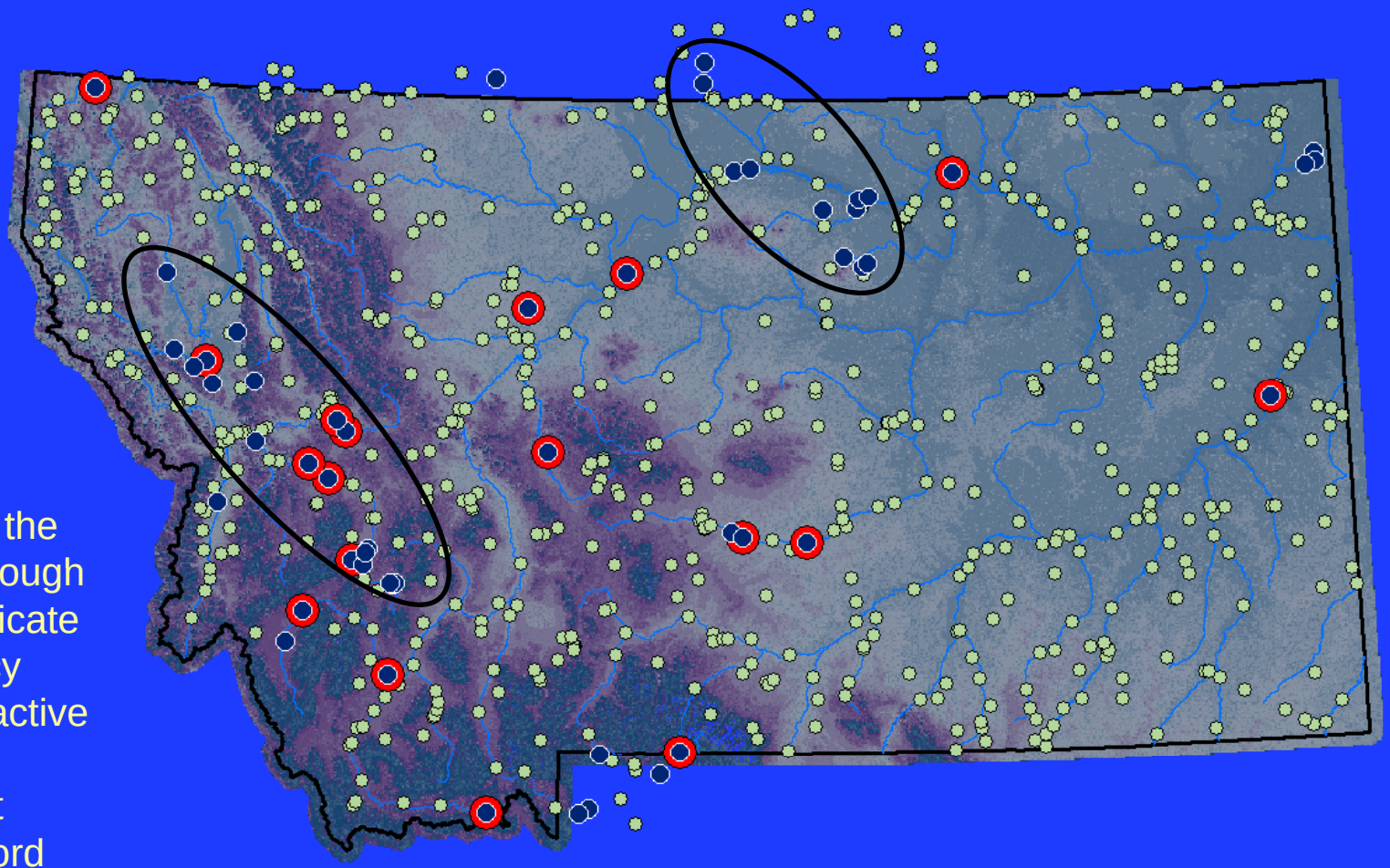
USGS

Reasons for new flood frequency analyses

- Most recent published frequencies (and regional regression equations) based on data through 1998
  - 11 additional years of data for existing gages
  - 18 additional gages with 10 or more years
- Recent climatic patterns have potential to substantially influence approaches to flood-frequency analyses
- Regional mixed-population analyses in northwestern Montana
- Report detailing mean, std. dev., skews, outliers, and multiple frequency curves for every station

USGS

Selected peak-flow gaging stations



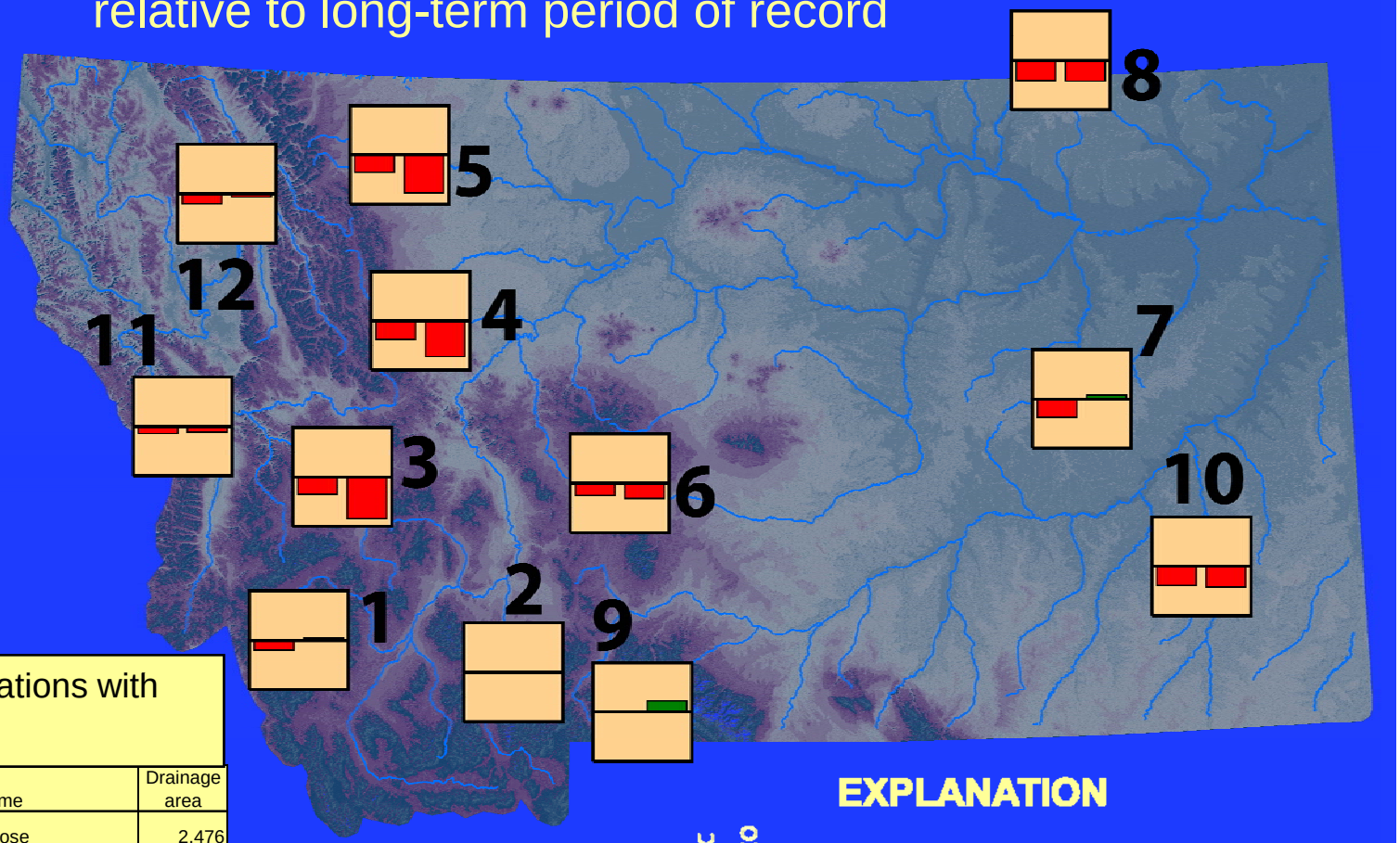
Two severe droughts from the mid-1980's through present complicate flood-frequency estimates for active stations with relatively short periods of record

EXPLANATION

- Stations reported in WRIR 03-4308 (660)
- Stations that have achieved 10 years of record since 1998 (18)
- Stations with records restricted to post-1985 (53)

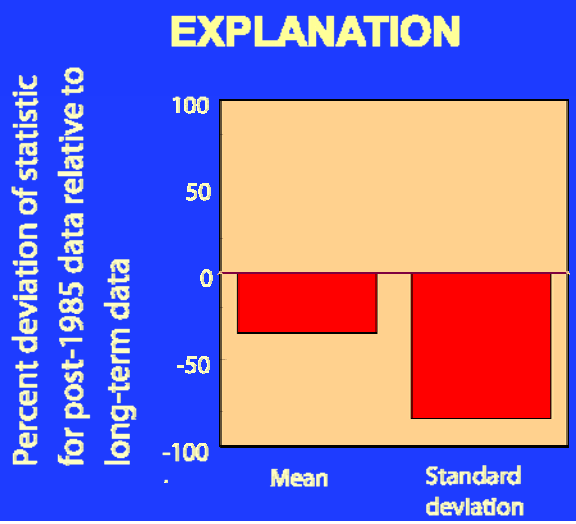
USGS

Percent difference in peak flow characteristics for 1985-2008 relative to long-term period of record



Selected unregulated stations with 72+ years of record

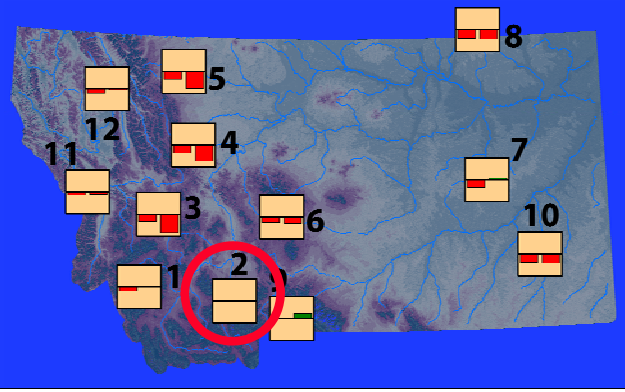
Map number	Station ID	Station Name	Drainage area
1	06025500	Big Hole River near Melrose	2,476
2	06052500	Gallatin River at Logan	1,795
3	06062500	Tenmile Creek near Rimini	31
4	06089000	Sun River near Vaughn	1,849
5	06099500	Marias River near Shelby	3,242
6	06120500	Musselshell River at Harlowton	1,125
7	06177500	Redwater River at Circle	547
8	06178000	Poplar River at international boundary	358
9	06192500	Yellowstone River near Livingston	3,551
10	06326500	Powder River near Locate	13,068
11	12354500	Clark Fork at St. Regis	10,709
12	12372000	Flathead River near Polson	7,096

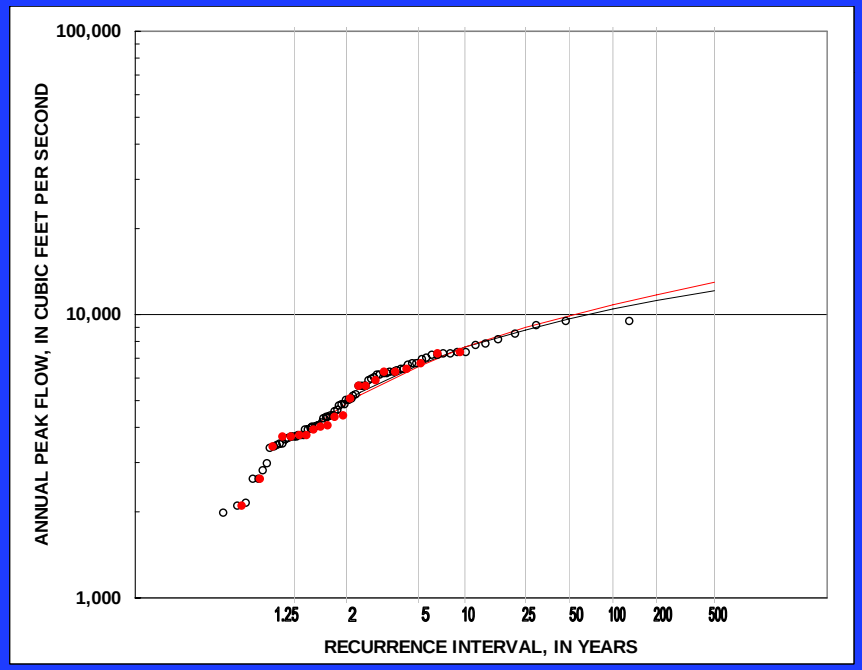


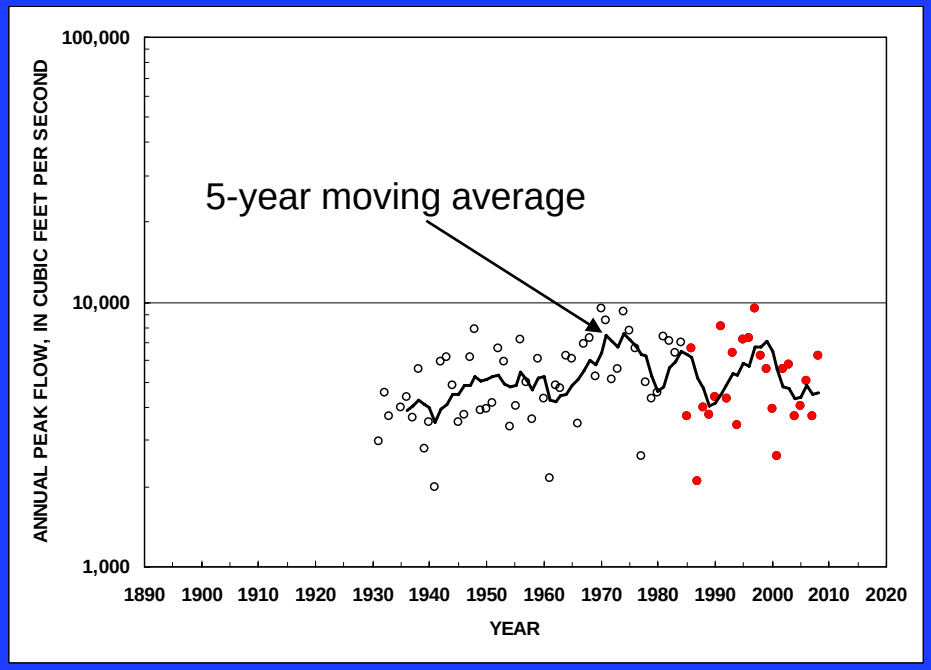
USGS 06052500 – Gallatin R. at Logan

Drainage area = 1,795 mi²

Comparison of flood-frequency estimates based on 1985-2008 versus long-term period of record







USGS

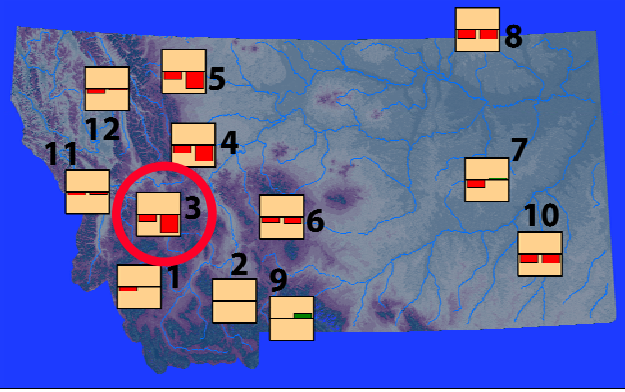
EXPLANATION

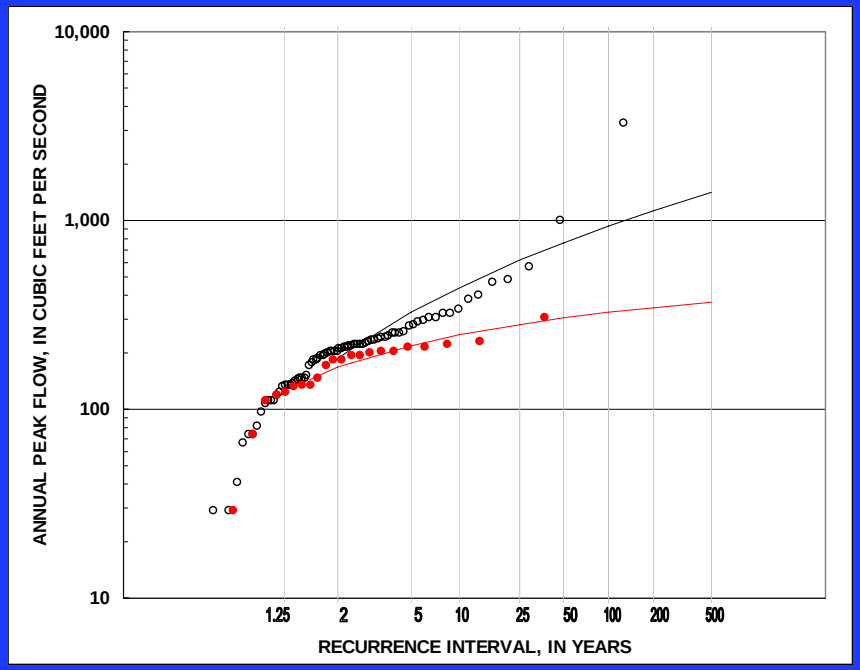
- Long-term period-of-record systematic peaks
- Post-1985 systematic peaks

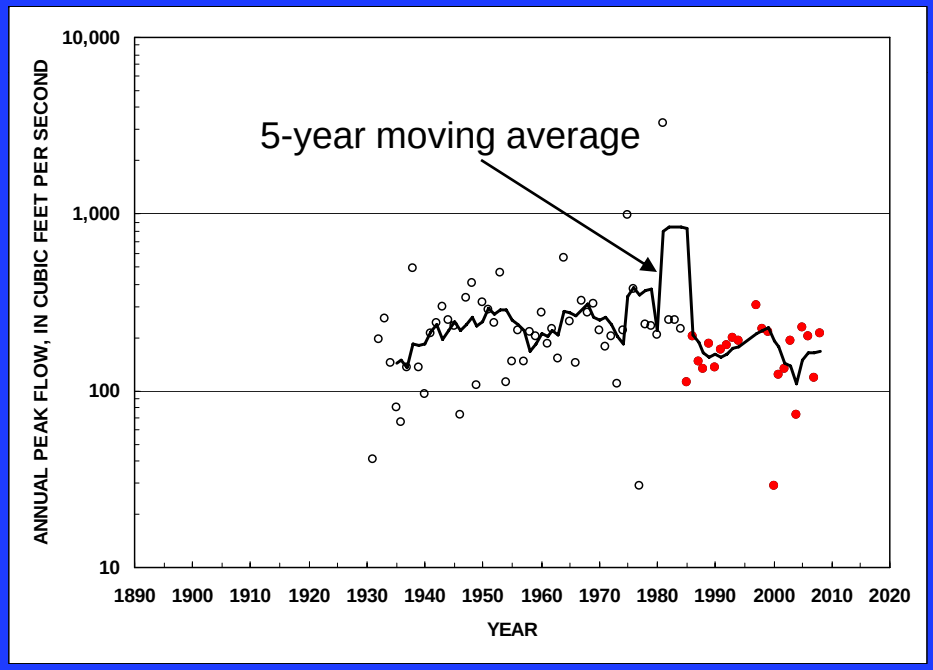
USGS 06062500 – Tenmile Cr. Nr Rimini

Drainage area = 30.9 mi²

Comparison of flood-frequency estimates based on 1985-2008 versus long-term period of record







USGS

EXPLANATION

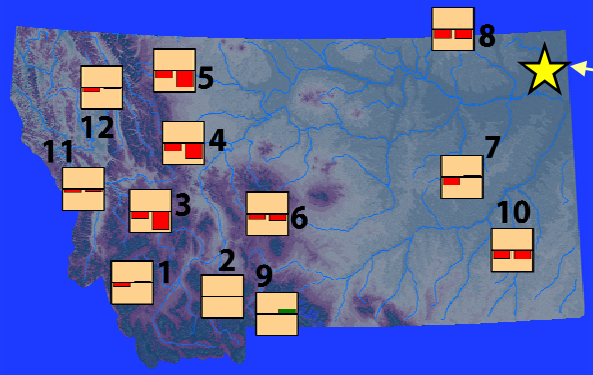
- ○ **Long-term period-of-record systematic peaks**
- ● **Post-1985 systematic peaks**

Research activities relating to period-of-record and stationarity issues

- Record-extension methods (B17b 2-station analysis and MOVE.1)
- Begin systematic tracking of stationarity in peak-flow records statewide
- Investigate methods for developing consistent flood-frequency estimates given stationarity uncertainties (moving base period, methods for adjusting for regional trends in means and standard deviations of peak flow series, investigation of nonstationary probability models)

USGS

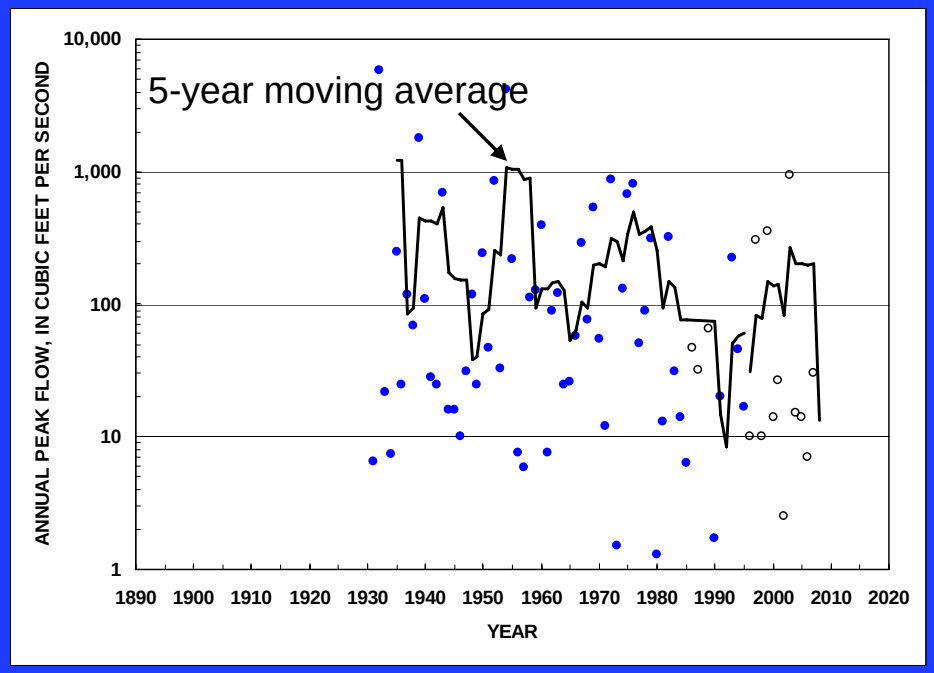
Example of application of B17B 2-station and MOVE.1 analyses to a short-term gaging station

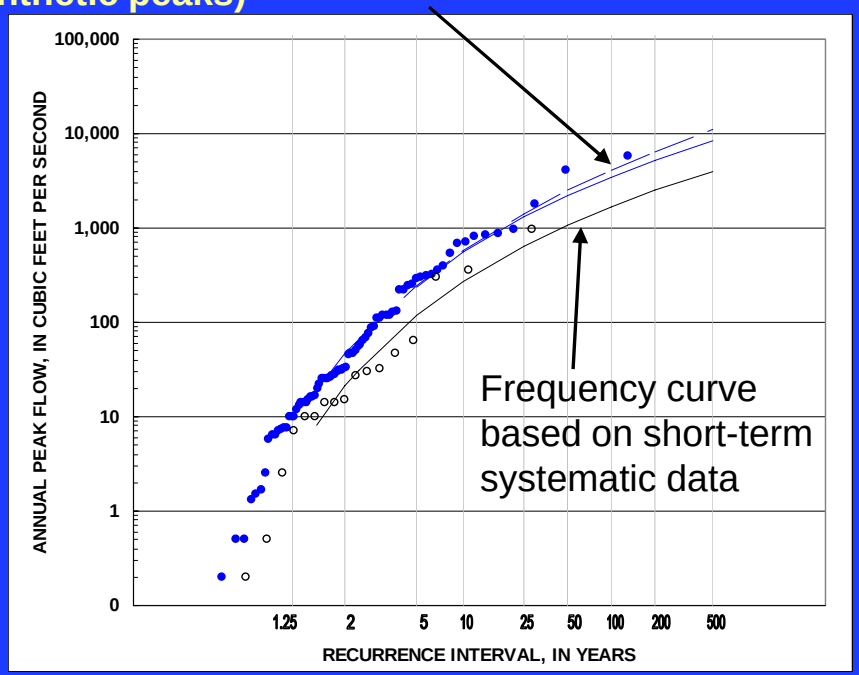


Lake Creek near Dagmar

Drainage area = 101 mi²
Period-of-record 1986-89, 1996-present

Frequency curves based on synthetic long-term period of record data (solid = 2 station analysis; dashed = log-Pearson III fit to synthetic peaks)





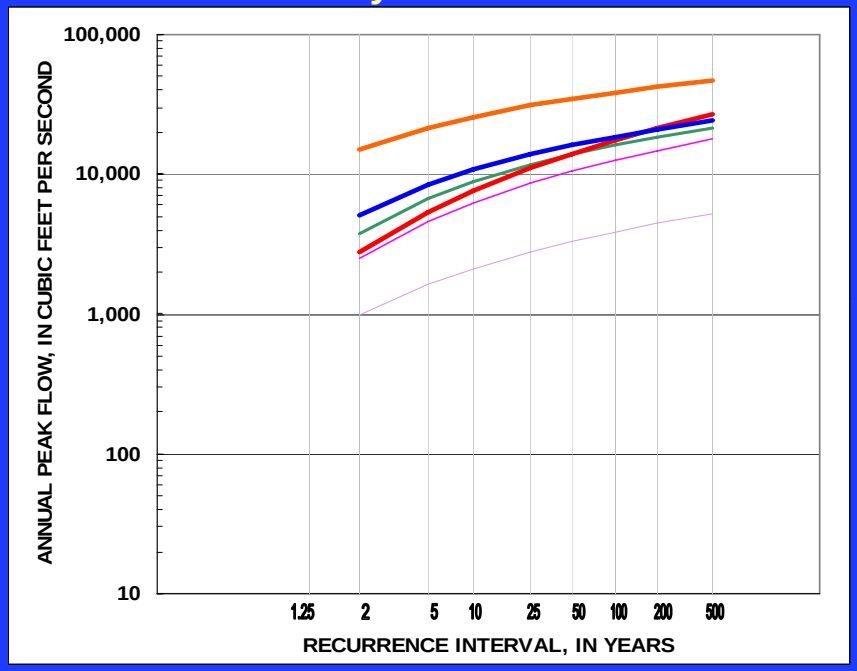
USGS

EXPLANATION

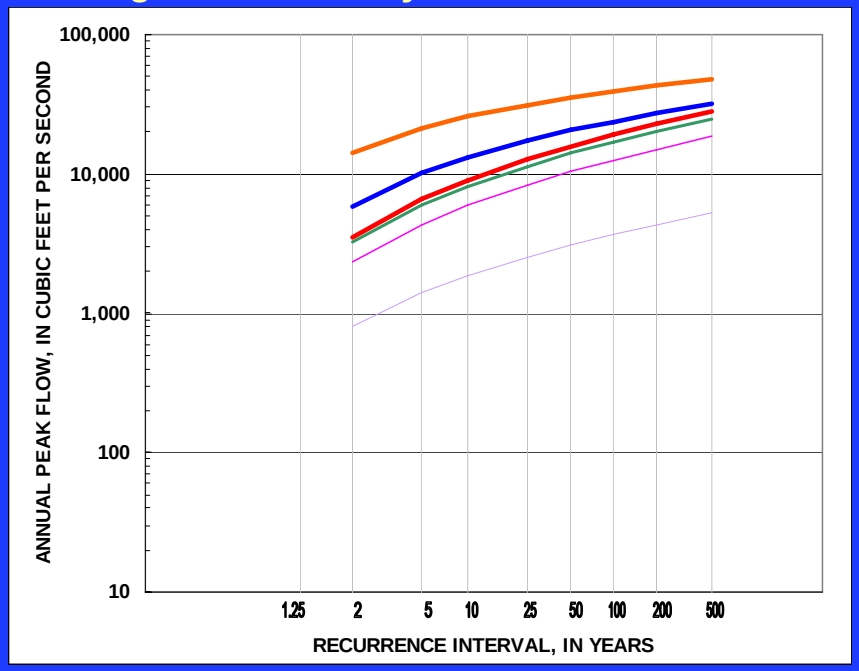
- ○ **Short-term period-of-record systematic peaks**
- ● **Synthetic (MOVE.1) long-term peak flows**

Examples of application of B17B 2-station analyses in the Clark Fork basin

Flood frequency estimates based on systematic record



Flood frequency estimates using 2-station analyses



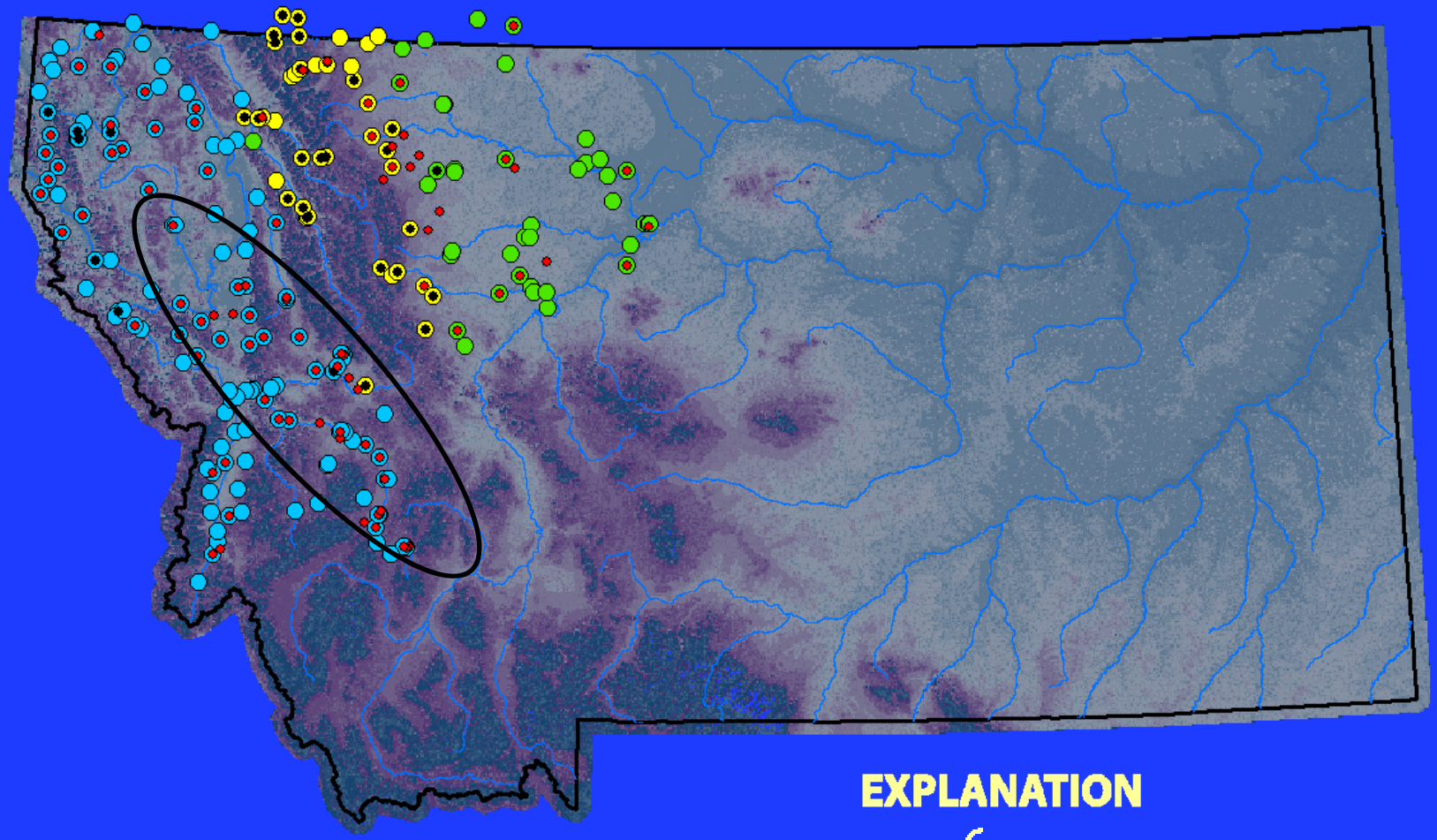
EXPLANATION

Mainstem Clark Fork gaging stations

- 12340500 – above Missoula
- 12334550 – at Turah Bridge
- 12331900 – near Clinton
- 12331801 – at Drummond
- 12324680 – at Gold Creek
- 12324200 – at Deer Lodge

USGS

Regional mixed-population analysis



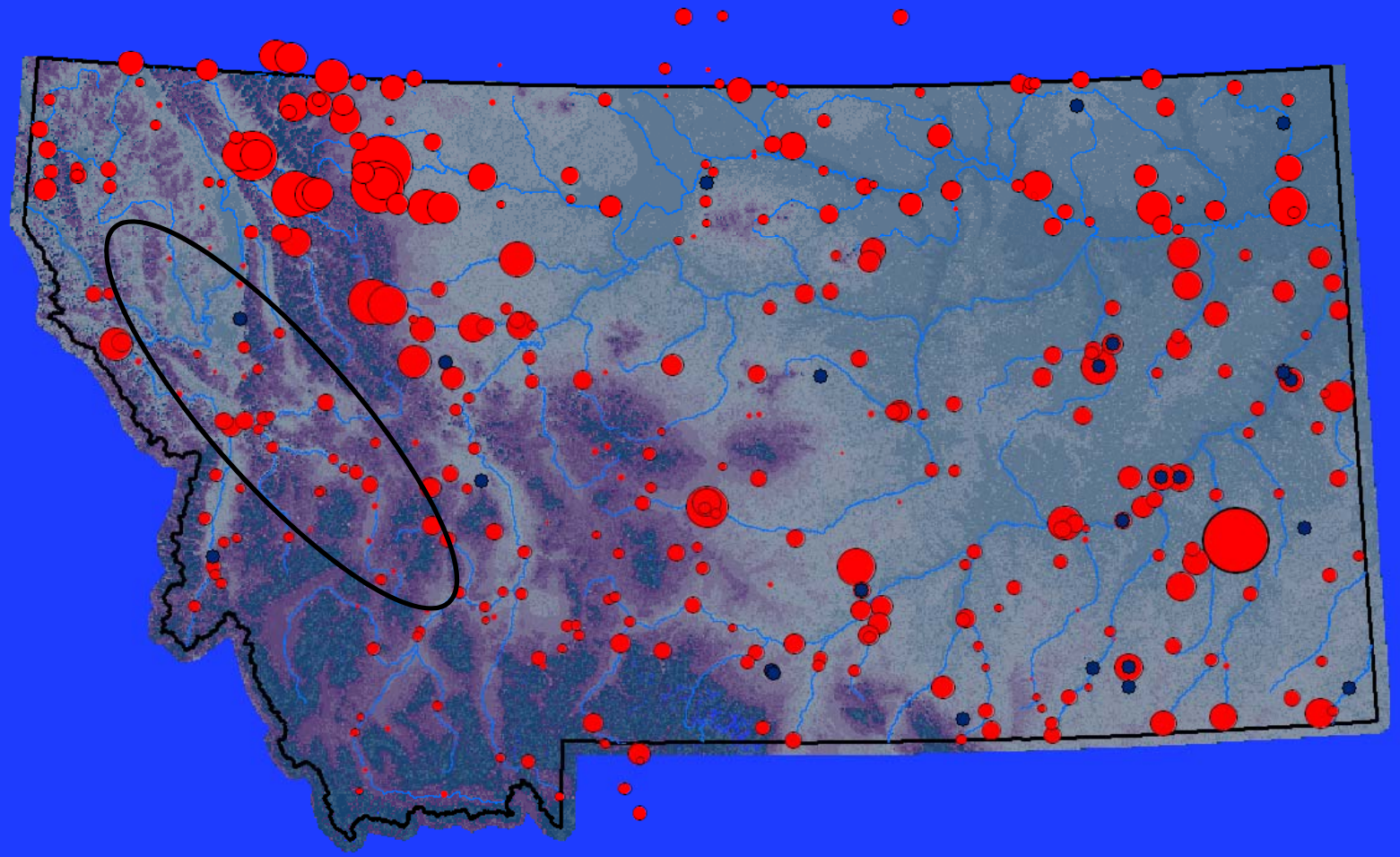
Stations reported in WRIR 03-4308

EXPLANATION

- West Region
- Northwest Region
- Northwest Foothills Region
- Station with mixed-population analysis
- Station not gaged during 1964

USGS

Normalized maximum recorded peak flows for gaging stations with 20+ years of record



EXPLANATION

Maximum recorded peak flow normalized to drainage area; Size of circle is proportional to magnitude

Stations with maximum recorded peak occuring after 1998

USGS

Future directions

- Perform detailed update of flood frequency estimates and low flow statistics for USGS gaging station network in Montana
- Update/develop regional regression equations using GIS-based basin characteristics
  - Update flood frequency regional regression equations
  - Develop low flow regional regression equations
- Implement StreamStats (*next presentation)*

USGS

Summary

- 11 additional years of record for existing gages
- 18 additional gages with 10 or more years
- Basic bulletin 17B log-Pearson III analyses plus where appropriate:
  - Period of record effects
  - Stationarity
  - Regional mixed-population analysis
- Report outlining details such as mean, standard deviation, skew, skew type, and outliers, and frequency curves reflecting additional methods used

USGS

USGS
science for a changing world

StreamStats-

Approaches for Estimating Basin and Streamflow Characteristics for Montana

In cooperation with
Montana Department of Natural Resources and Conservation

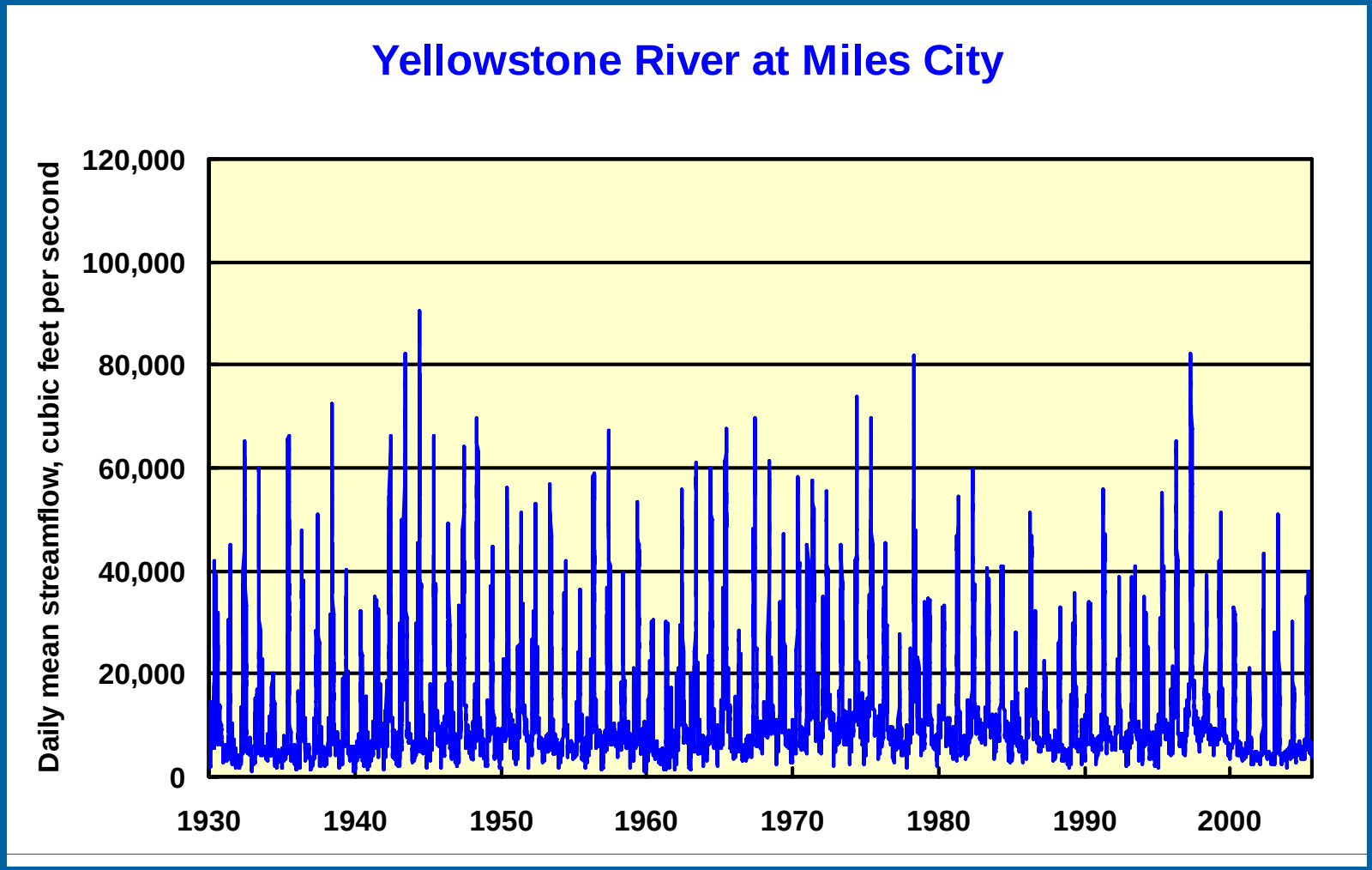
U.S. Department of the Interior
U.S. Geological Survey

What are Streamflow Characteristics?

- Ways to summarize streamflow data
  - Basic summary statistics
    - Range (e.g. max, min)
    - Mean (e.g. daily, monthly)
  - Flow-duration analyses (e.g. exceedance flows)
  - Frequency analyses (e.g. 100-year flood)
- Intended use determines type of analyses and data period

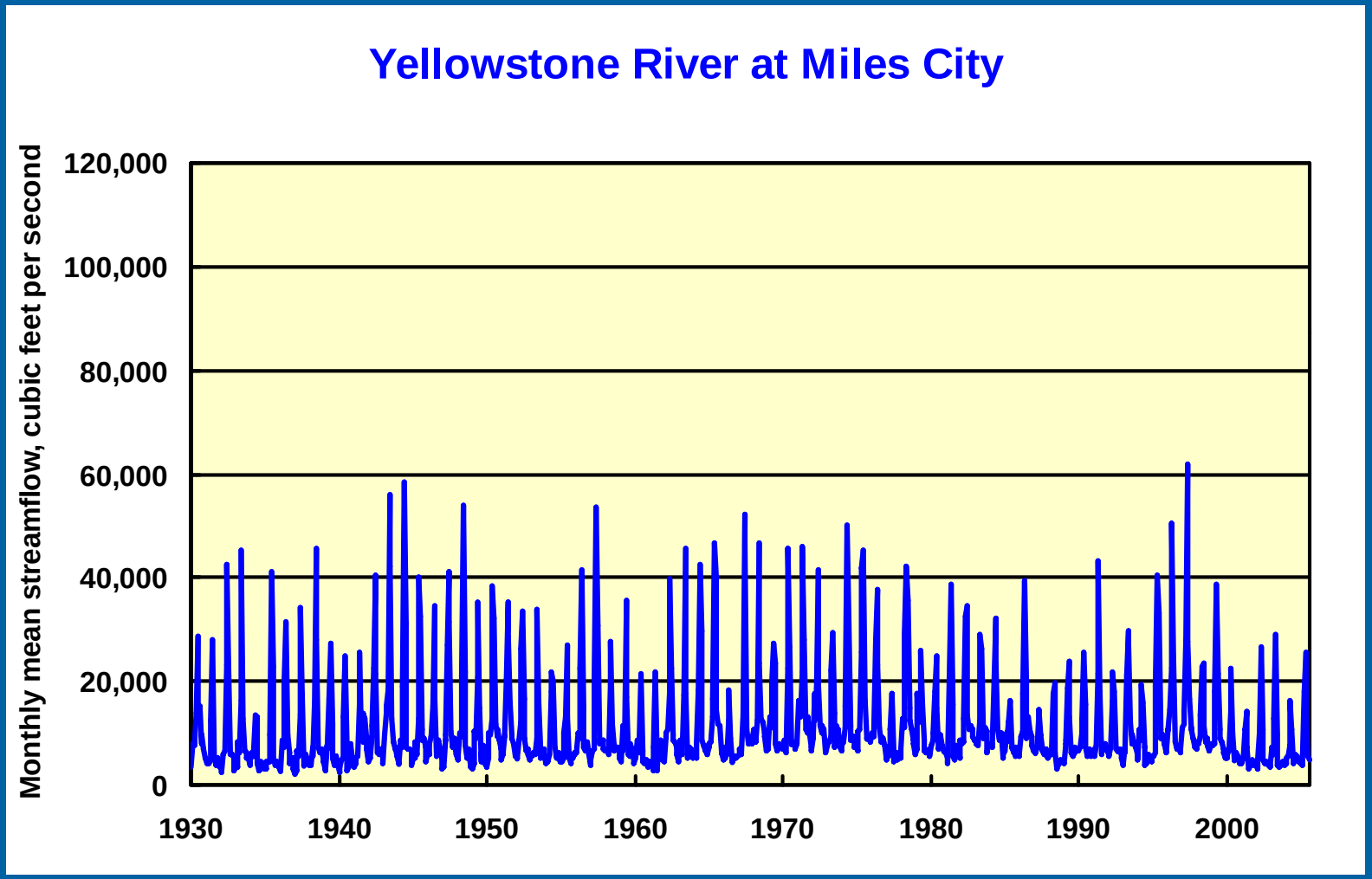
USGS

Daily Mean Streamflow



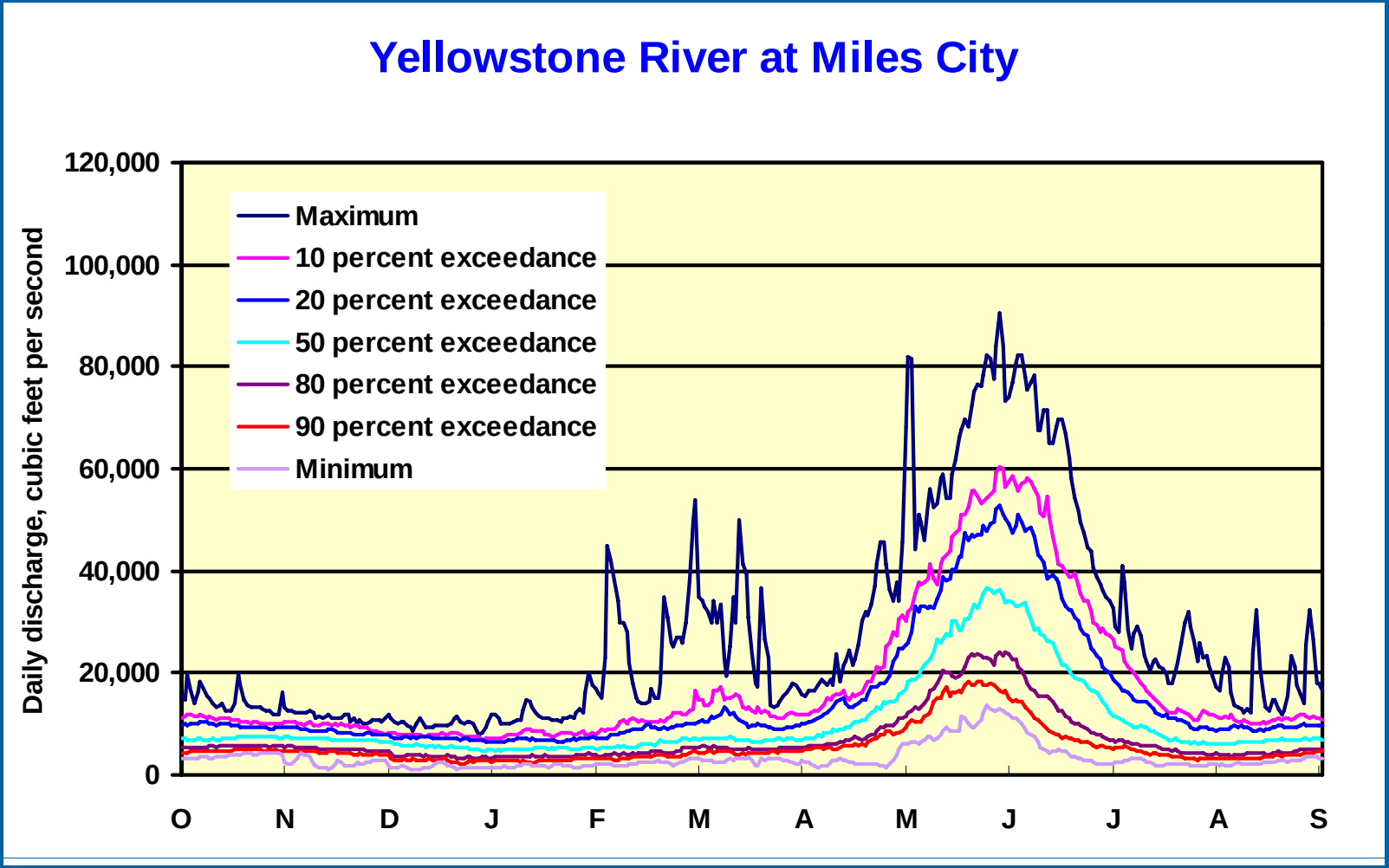
USGS

Monthly Mean Streamflow



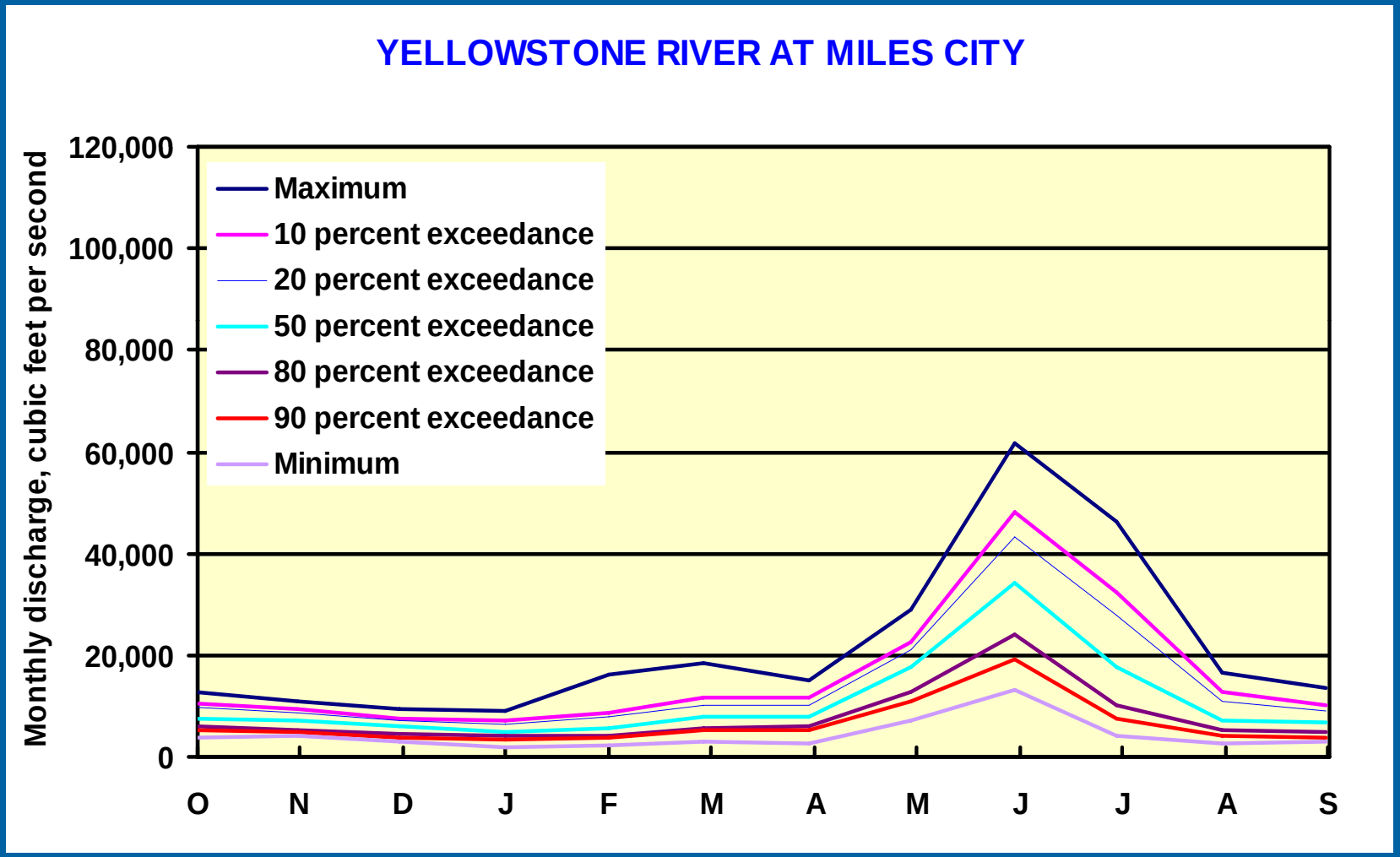
USGS

Daily Duration Hydrograph



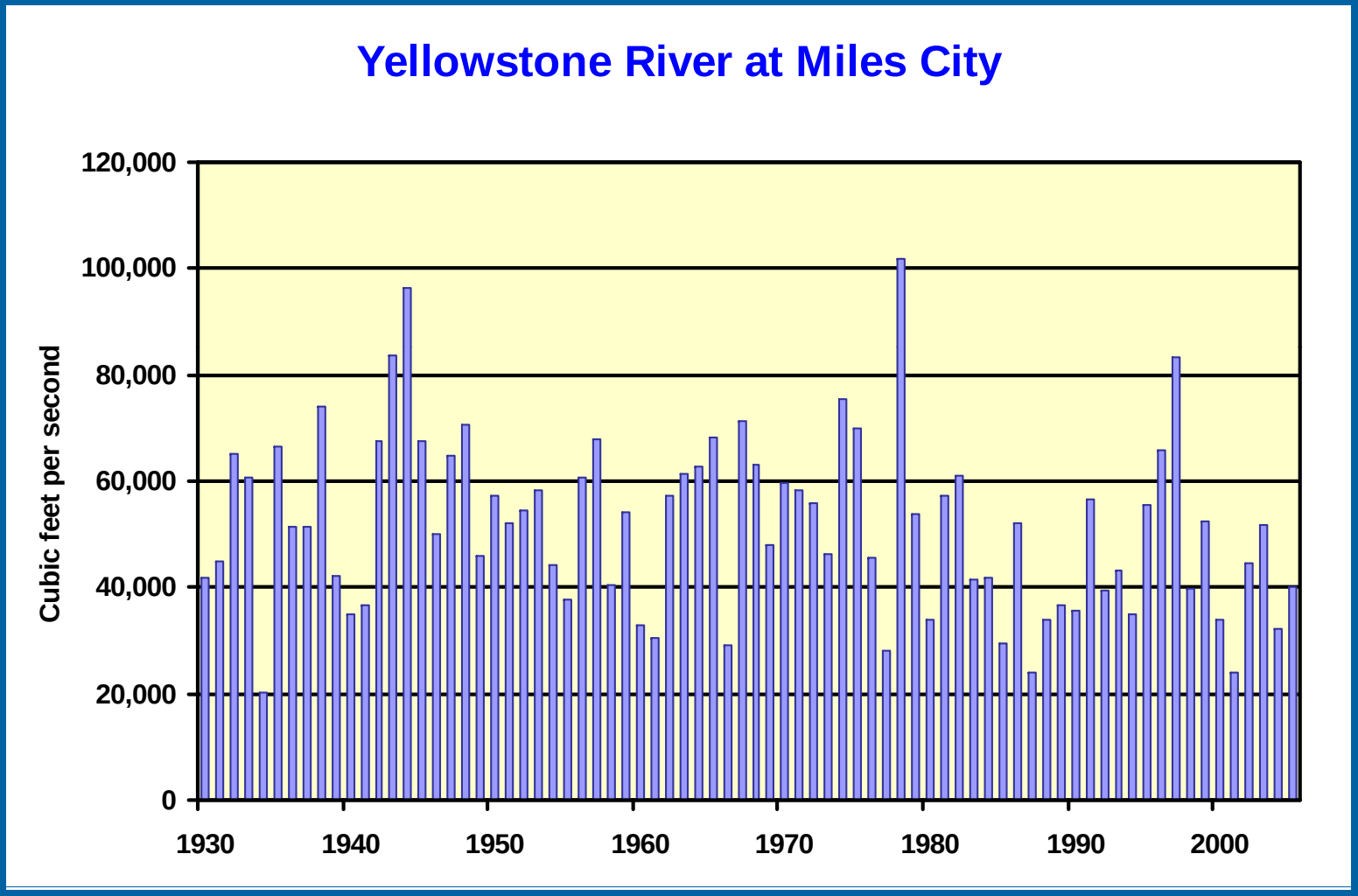
USGS

Monthly Duration Hydrograph



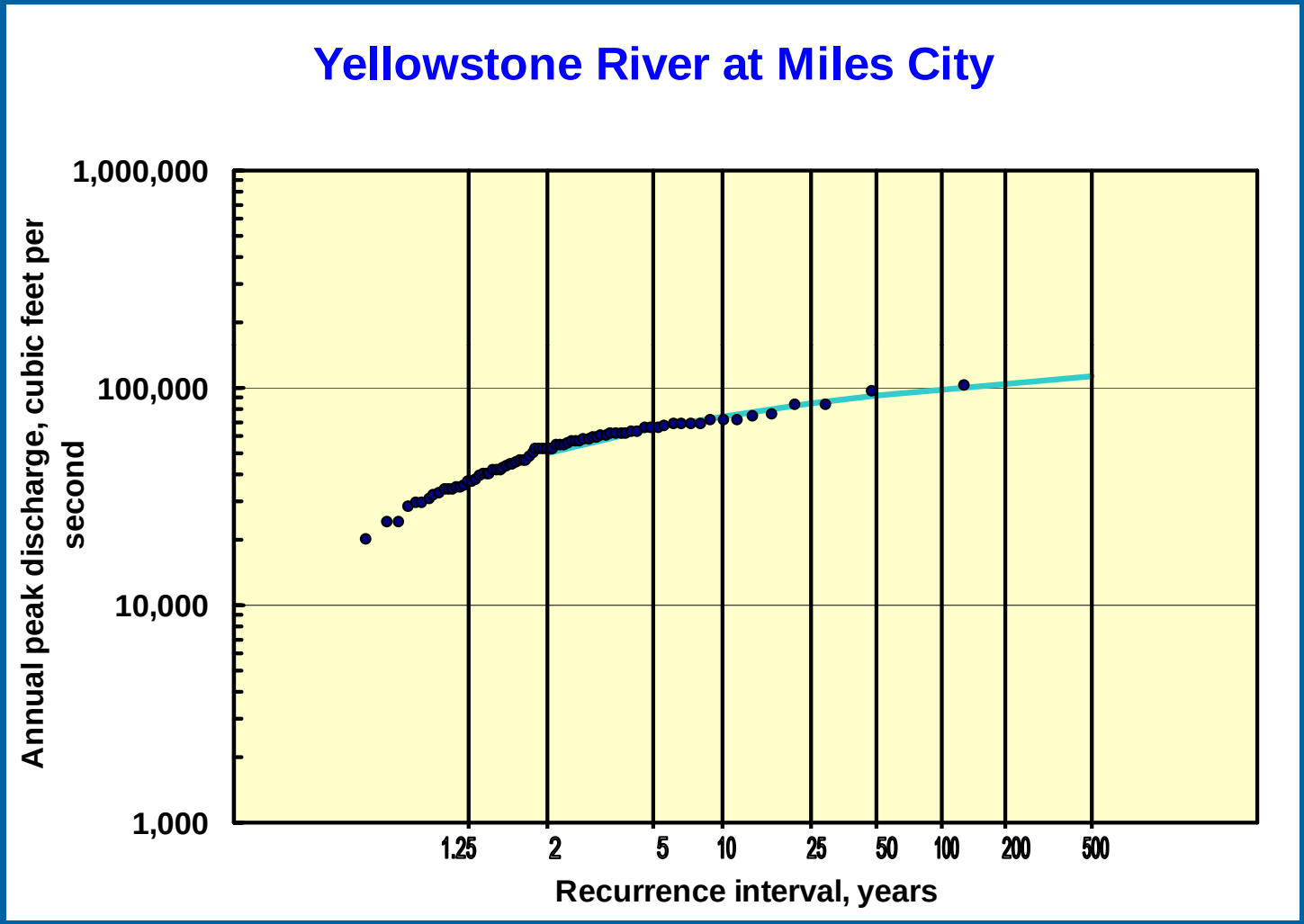
USGS

Annual Peak Streamflow



USGS

Peak Flow Frequency



USGS

Estimating Streamflow Characteristics

- Streamflow characteristics also are needed at ungaged sites
- Streamflow characteristics are a function of topographic, climatic, and other environmental characteristics of drainage basins
- Regression analyses can be used to relate streamflow characteristics to basin characteristics

USGS

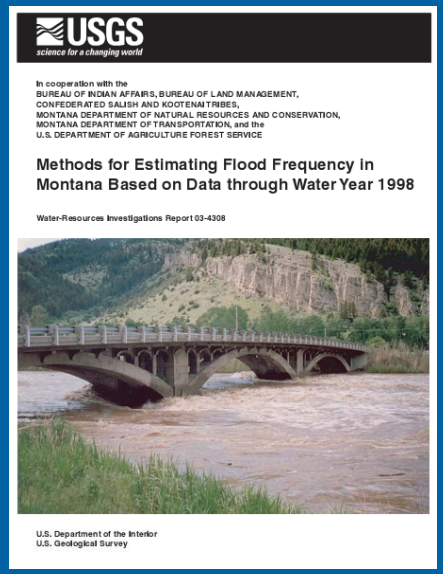
Example Regression Equations

- Regression equations might take the form:

$$Q_{100} = 0.352 * CA^{0.960} * S^{1.25}$$

or

$$Q_{100} = 362 * CA^{0.521} * PII^{4.47}$$



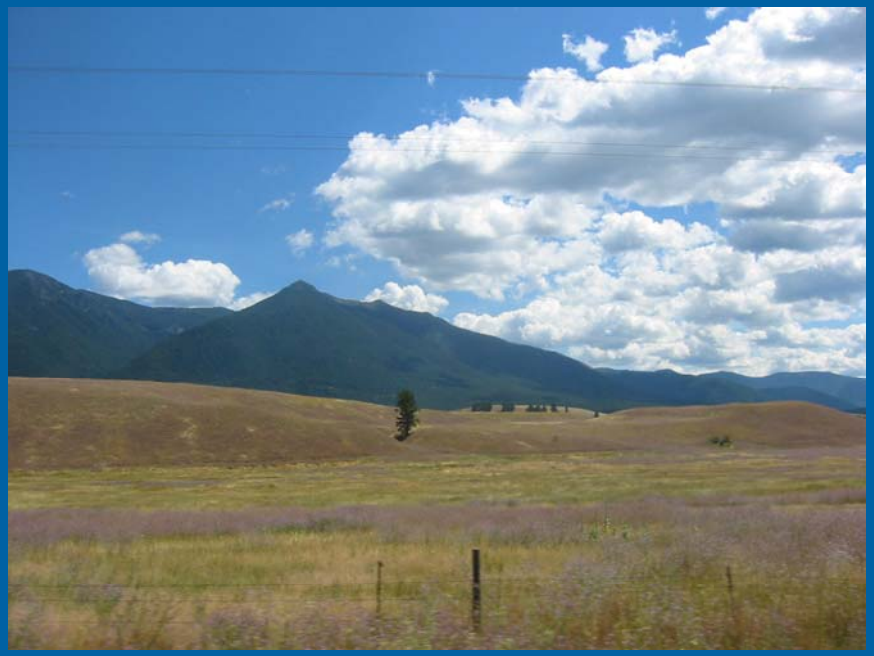
where:

Q_{100}	is the 100-year flood
CA	is contributing drainage area, in square miles
S	is main-channel slope, in feet per mile
PII	is precipitation intensity index, in inches

Based on manually determined basin characteristics

USGS

What are Basin Characteristics?



- Topographic
  - Drainage area
  - Slope
  - Elevation
  - Shape
- Non-topographic
  - Climatic characteristics, e.g. precipitation, evaporation, air temperature
  - Land-cover/use
  - Soils/geology

USGS

Estimating Basin Characteristics – Manual Methods

- Advantages
  - High accuracy for some characteristics (drainage-basin boundary and area determination)
- Limitations
  - Labor intensive
  - Dependent upon data availability
  - Accuracy and consistency

USGS

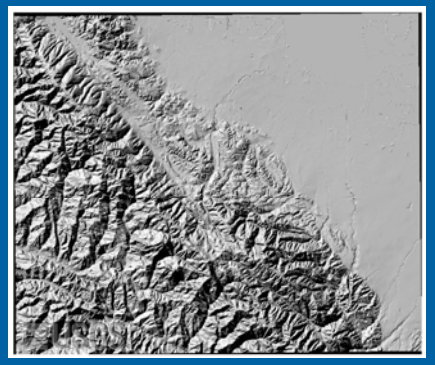
Estimating Basin Characteristics – GIS Methods

- Topographic characteristics
  - based on digital analysis of elevation and hydrography geospatial datasets
- Non-topographic characteristics
  - based on digital analysis of environmental geospatial datasets
- Datasets clipped to drainage area boundary and summarized (e.g. mean annual precipitation in basin)

USGS

Estimating Basin Characteristics GIS Methods – Available Datasets

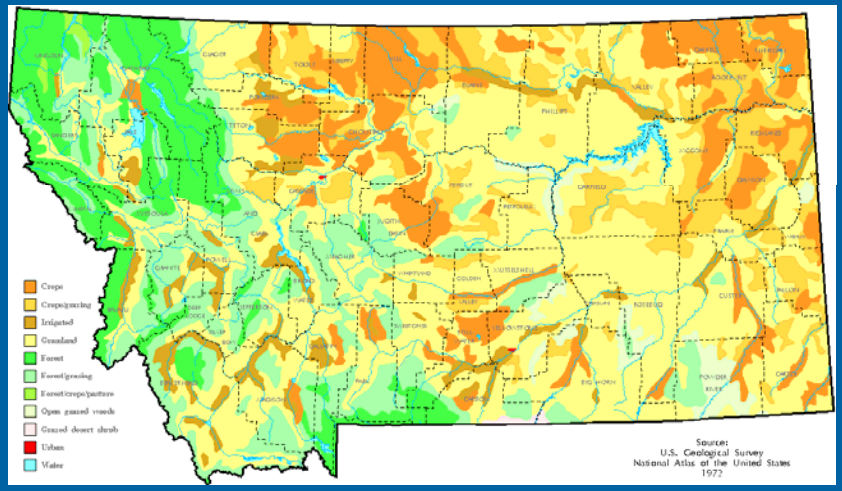
- Topographic
  - Digital elevation model (DEM) data
    - e.g. National Elevation Dataset (NED)
  - Hydrographic data
    - e.g. National Hydrography Dataset (NHD)
  - Integrated database analysis
    - ARCHYDRO routines
  - Hydrologically conditioned geospatial datasets
    - Elevation Derivatives for National Applications (EDNA)
    - NHDPlus
    - WBD



USGS

GIS Datasets and Methods

- Non-Topographic
  - Climatic data
    - e.g. Parameter-elevation Regressions on Independent Slopes Model (PRISM) data – air temp., mean annual precip., 1,000 m resolution
  - Land-cover data
    - e.g. National Land Cover Dataset (NLCD 1992)
  - Soils data
    - e.g. State Soil Geographic Database (STATSGO)
  - Geology data
    - e.g. digitized geologic map of Montana (1955) – surficial geology, 500K



USGS

Estimating Basin Characteristics – GIS Methods

- Advantages
  - Quick and convenient
  - Greater availability of recent data
  - Consistent calculation of basin characteristics
  - Potential to improve regional regression equations
  - Automation makes equations easier to use
- Limitations
  - Accuracy (?)

USGS

Estimating Basin Characteristics – Next Steps

- Estimate *new* basin characteristics for all gaged sites using GIS methods
- Compare *new* basin characteristics estimated with GIS methods to the *old* basin characteristics estimated manually
- Compare streamflow statistics computed using *new* vs. *old* basin characteristics
- Develop regression equations to estimate streamflow statistics using *new* basin characteristics

USGS

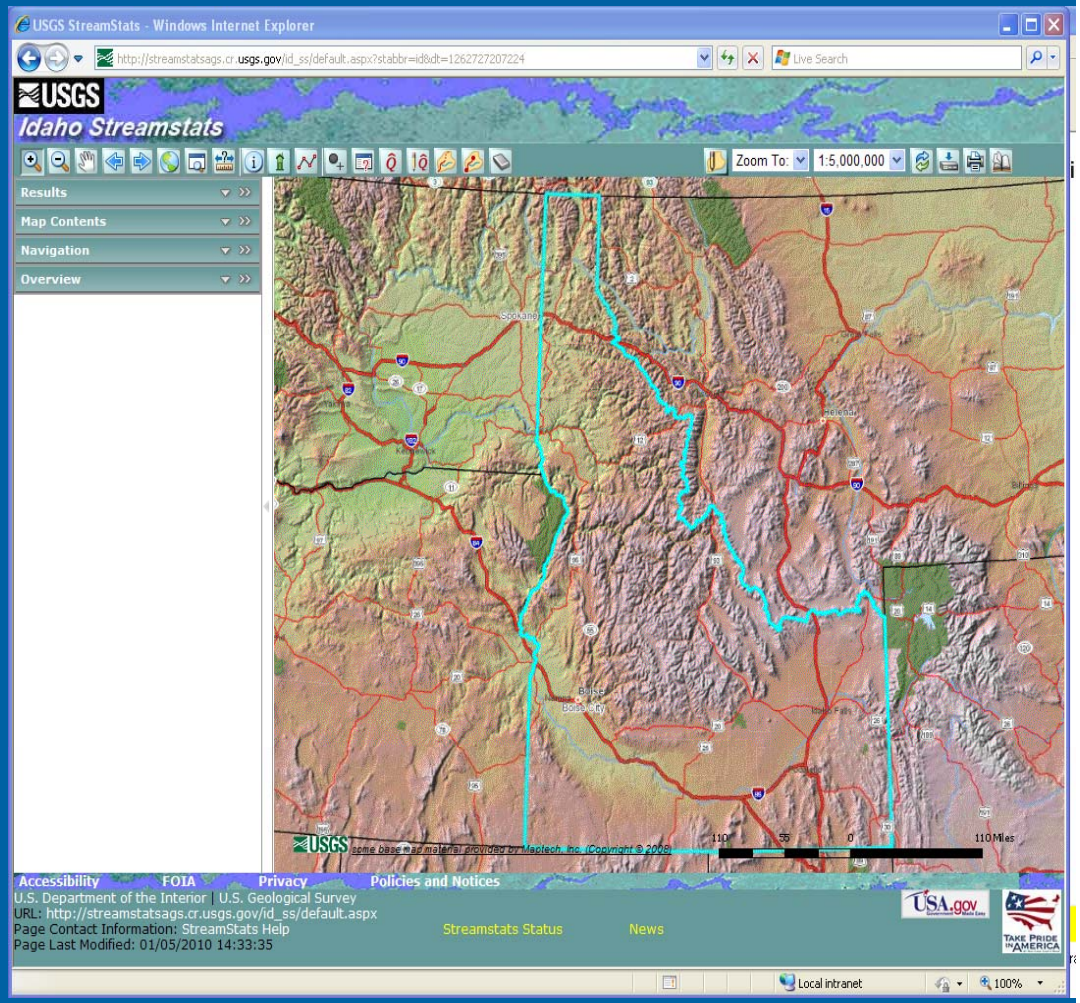
StreamStats - Web Application

- Nationally standardized web tool developed by USGS Office of Surface Water
- For *gaged* sites: provides published streamflow statistics and basin characteristics
- For *ungaged* sites: solves previously published regression equations to estimate streamflow statistics
- User access via an interactive map

USGS

Idaho StreamStats

- National StreamStats page: http://water.usgs.gov/osw/streamstats/index.html
- Idaho StreamStats page: http://streamstats.usgs.gov/html/idaho.html



USGS

StreamStats Implementation Plan for Montana

- Form StreamStats Interest Group (Jim Robinson, DNRC)
- Identify cooperative funding partners
- Implement StreamStats using NHDPlus medium resolution DEM/Hydrography (30-meter; 1:100,000 scale)
- Pursue StreamStats implementation concurrently with development of flood frequencies, and regional regression equations
- Consider developing equations to estimate additional flow statistics, using basin characteristics developed using GIS methods

USGS

Summary

- USGS Montana Water Science Center is transitioning to the use of GIS methods to determine basin characteristics
- GIS-computed basin characteristics will enable implementation of StreamStats for Montana with cooperator support
- StreamStats will provide estimates of streamflow statistics for gaged and ungaged sites
- StreamStats uses an interactive map accessed via the web to provide the information to the public
- Implementation will require cooperator support and take several years

USGS